September 2003

Economic and Statistical Analysis of Changing the Protein Calibrations for all Major Classes of Wheat

Abstract

The USDA/Grain Inspection, Packers and Stockyards Administration (GIPSA) is considering changing its protein testing program to use a global Artificial Neural Network (ANN) calibration developed by FOSS Tecator rather than GIPSA-developed calibrations [i.e., Partial Least Squares (PLS)]. Before deciding whether to migrate to the ANN approach, GIPSA is considering its potential economic impact on the wheat market and the accuracy of the method. A GIPSA-conducted pilot study found that, overall, the ANN predicts protein content with the same accuracy as the PLS. Also, an analysis of the pilot study data found that a switch in the protein calibrations would result in an overall increase of $70,000 in the value of wheat stocks, the equivalent of 0.004 percent of total wheat value at time of the analysis.

Summary

GIPSA is evaluating the effect on Near-Infrared Transmittance (NIRT) wheat protein test results of testing with the current “in-house” calibrations (i.e., PLS) versus a global ANN calibration developed by Foss Tecator in conjunction with GIPSA, the Canadian Grain Commission, and representatives from Europe and Australia. Two of the factors GIPSA is considering before deciding whether to migrate to an ANN calibration are the economic impact on the wheat market and the accuracy of the ANN calibration (i.e., statistical analysis). The economic impact is addressed in this paper; the statistical analysis appears in APPENDIX A.

In the context of this analysis, “economic impact” is defined as any change in the value of wheat stocks resulting from an instantaneous switch from one calibration to the other. The economic impact is calculated as the net change in the value of the ending stocks for each class of wheat due to the calibration change had it occurred at the end of the crop/marketing year, May 31, 2003. The six major market classes are Hard Red Winter wheat (HRW), Hard Red Spring wheat (HRS), Hard White wheat (HDWH), Soft White wheat (SWH), Soft Red Winter wheat (SRW), and Durum wheat (DU). A switch from the PLS to the ANN calibration would not affect the HRS, HDWH, or SRW stocks. The change would decrease the value of HRW stocks by $470,000; increase SWH stocks by $240,000; and increase DU stocks by $300,000 (Table 1). Overall, the value of wheat stocks would increase $70,000, or 0.004 percent of total wheat value as of the end of the

2002/2003 wheat marketing year.[1] This increase is negligible compared to the value of the entire crop and would likely have no serious impact on the wheat market. [2]

Table 1. Summary of Potential Economic Impact

Impact by class of wheat	- Wheat Class -		
	Hard Red Winter (HRW)	**Soft White (SWH)**	**Durum (DU)[3]**
Net Impact	-\$0.47 million (-0.06%Δ)	+\$0.24 million (+0.09%Δ)	+\$0.30 million (+1.0%Δ)
Stocks at end of 2002/2003 marketing year (i.e., 5/31/03)	189 m. Bu. - or - 5.10 MMT	74 m Bu. - or - 2.00 MMT	6.2 m Bu. - or - 0.17 MMT
Value of stocks using PLS calibration	\$725.94 million	\$264.93 million	\$30.94 million
Value of stocks using ANN calibration	\$725.47 million	\$265.17 million	\$31.25 million

Background

GIPSA is considering switching the calibrations for its protein testing program from GIPSA-developed PLS calibrations to a global ANN calibration developed by FOSS Tecator in conjunction with GIPSA, the Canadian Grain Commission, and representatives from Europe and Australia. Table 2 shows a comparison of the basic features of the PLS and ANN calibrations.

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[1] The total value of all wheat was estimated using the U.S. wheat ending stocks published in the USDA/World Agricultural Outlook Board's *World Agricultural Supply and Demand Estimates* and the national average prices received by farmers published in the USDA/Economic Research Service's *Wheat Outlook.*

[2] This economic impact analysis is valid for the data and market conditions described in this report. GIPSA makes no assumptions as to what the impact would be if a different ANN calibration were used or if stock levels and premiums/discounts were other than what are provided in this report.

[3] Figures provided are for Durum wheat originating in California and Arizona [i.e., desert Southwest Durum wheat (refer to the write-up on Durum wheat for additional detail)].

Table 2. Basic Features of the PLS and ANN Calibrations

PLS	ANN
GIPSA develops PLS calibrations	FOSS Tecator has developed a global ANN calibration in conjunction with GIPSA, Canadian Grain Commission, and representatives from Europe and Australia
PLS calibrations can fit only linear data	ANN is a different, more complex mathematical approach than PLS. The ANN calibration can fit non-linear data.
GIPSA maintains a separate PLS calibration for each class of wheat	A single ANN calibration can be used for all classes of wheat (and possibly barley)
GIPSA develops PLS calibrations based on samples of U.S.-grown wheat from several crop years	FOSS Tecator used more than 30,000 samples from around the world to develop the current ANN calibration
GIPSA/official system uses NIRT instruments manufactured by FOSS Tecator	GIPSA/official system would use NIRT instruments manufactured by FOSS Tecator
Standard reference method is the Combustion Nitrogen Analyzer (CNA)	Standard reference method is the Combustion Nitrogen Analyzer (CNA)

For the past several years, GIPSA has presented information about its protein testing program to the Grain Inspection Advisory Committee (GIAC). In May 2002, the GIAC resolved that:

> GIPSA should thoroughly evaluate the technical, operational, and business aspects of the ANN calibration system in order to better understand the benefits and consequences of changing the calibration process. GIPSA should not limit this benefit and consequence analysis to only the official inspection program but also should consider the benefits and consequences to the United States grain industry. Further, GIPSA should report these findings to the Advisory Committee so the Committee may provide guidance and advice to the GIPSA before a final decision is made.

In concurrence with the GIAC's resolution, GIPSA conducted a pilot study that: (1) compared wheat protein results on current market samples using the current calibrations and the ANN calibration; (2) compared PLS and ANN to the reference method (CNA); (3) included all major production/handling locations; and (4) included all major wheat classes.

Methodology

GIPSA considered several approaches in calculating "economic impact." For example, GIPSA considered calculating the instantaneous change in the value of wheat stocks resulting from "flipping the switch" (i.e., what change, if any, would occur in the value of wheat stocks immediately before and after implementing a calibration change). GIPSA also considered calculating a longer-term change and applying long-term averages for premiums, discounts, and stocks. GIPSA also considered calculating the net change in the income of a particular marketing segment, such as wheat producers.

While all approaches had merit, GIPSA chose to evaluate the instantaneous change in the value of wheat stocks resulting from a change from the PLS calibrations to the ANN calibration. This approach was selected, in part, to coincide with the end of the wheat marketing year, a time when GIPSA would be most likely to implement such a change in the wheat protein program. Further, implementation, if it occurs, will be instantaneous at a specific point in time across the national inspection system. While GIPSA is determining the impact of changing one specific factor at a discrete point in time, it is important to remember that numerous externalities, such as global supply and demand, wheat futures prices, stocks-to-use ratios, world trade, weather, and transportation costs, have far greater impacts on a wheat prices than protein content. In other words, overall market forces impact price discovery and the ultimate value of wheat.

GIPSA relied on an agency-conducted pilot study to determine the impact of an instantaneous change in the calibration.[4] The study was designed so that equal numbers of samples were collected from various regions by protein ranges, allowing GIPSA to gather equal information from areas of lesser production. Various GIPSA field and sub-offices analyzed the samples for protein content, and forwarded the samples to GIPSA's Technical Center for protein analysis using several master NIRT instruments and the standard reference method (i.e., CNA).[5] To calculate the economic impact, GIPSA analyzed the pilot study data for "domestic" samples (i.e., PLS and ANN results for non-export samples which were run on field and sub- office NIRT instruments).[6] GIPSA focused on the domestic sample data because the export data were too highly concentrated around market-driven, specific protein levels for each class. Further, since

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[4] GIPSA acknowledges the efforts of Mr. Robert Lijewski, GIPSA's' Policy and Procedures Branch, who designed and coordinated the pilot study. Anyone wishing more detailed information about the pilot study may contact Mr. Lijewski at Robert.S.Lijewski@usda.gov or (202) 720-0224.

[5] GIPSA acknowledges the staff of GIPSA's field/sub-offices and Technical Center who were involved in collecting and analyzing samples. The field offices/sub-offices involved are located in Grand Forks, North Dakota; Kansas City, Missouri; Moscow, Idaho; Minneapolis, Minnesota; New Orleans, Louisiana; Olympia, Washington; Portland, Oregon; Sacramento, California; Toledo, Ohio; Stuttgart, Arkansas; and Wichita, Kansas.

Several other offices in Corpus Christi, Texas, Duluth, Minnesota, and League City, Texas, also participated in the pilot study, but these offices only ran "export" samples.

[6] GIPSA acknowledges the assistance of Mr. Owen Ecker, GIPSA's Data and Information Analysis Branch, whose statistical assistance and expertise were invaluable.

HDWH is primarily grown under contract, GIPSA was unable to obtain export samples through the official system.

For the economic analysis, individual pilot sample results were weighted to account for the differences in production for each class of wheat, and to best reflect how the wheat is actually distributed in the country as a whole. The weighted results reflect U.S. production by class, "typical protein distribution" (based on the distribution data in GIPSA's National Quality Database data), and collection location. For example, assigning the same "weight" to HDWH and HRW results would have been misleading -- HDWH accounts for less than 1 percent of all U.S. wheat production, and HRW accounts for over 40 percent. Results for the individual pilot samples were reported to the nearest hundredth, but in calculating the economic impact, the weighted results were rounded to the nearest tenth to coincide with how protein is reflected in premium and discounts schedules.

The economic impact is the net change in the value of the 2002/2003 ending stocks for HRW, HRS, HDWH, SWH, SRW, and DU due to an instantaneous change in the protein calibrations from PLS to ANN. The value before the change (i.e., PLS calibration) for each class is the sum of stocks at each 0.1 percent protein increment multiplied by the market price. Similarly, the value after the change (i.e., ANN calibration) is the sum of stocks at each 0.1 percent protein increment for each class multiplied by the market price for the appropriate protein level. For example, the ANN, on average, ran 0.1 percent less than the PLS for HRW. Therefore, the value of HRW using the ANN calibration was calculated as the sum of stocks at each 0.1 percent protein increment multiplied by the market price for the next lower protein level (i.e., minus 0.1 percent). To obtain the total impact, GIPSA summed the results for all classes. GIPSA assumed no significant impact on other wheat classes (i.e., Mixed and Unclassed) since the official system inspects insignificant quantities of these classes.

Information and Data Sources Used

For HRW, HRS, SWH, SRW, and DU, GIPSA used ending stock data from the September 2003, issue of the USDA World Agricultural Outlook Board's (WAOB) publication *World Agricultural Supply and Demand Estimates* (WASDE), which forecasted wheat stocks by class as of May 31, 2003, the end of the 2002/2003 marketing year. The WASDE report does not distinguish between HDWH and SWH, and reports only a total for White wheat stocks. White wheat stocks are assumed to consist predominantly of SWH given the minimal supply of HDWH relative to SWH. To distinguish between the two classes, this study used U.S. Wheat Associates' estimate for SWH stocks. HDWH stocks were then calculated as the difference between the WASDE estimate of the White wheat stocks and the U.S. Wheat Associate's estimate of SWH.

HRW, HRS, HDWH, SWH, SRW, and DU stocks were broken down by protein level (at 0.1 percent increments) using data from GIPSA's National Quality Database. Protein was reported on a standard 12 percent moisture basis.

Information about recent years' average crop quality, including protein content, was from the *2002 Crop Quality Report* published by U.S. Wheat Associates. Supply and demand data for each wheat class were from the September 2003, issue of the WASDE.

The analysis used pricing information for May 30, 2003, the last day of the 2002/2003 marketing year for which pricing was available, from the USDA Farm Service Agency (FSA) Bulk Commodity Division. FSA pricing data were not available for SWH and DU (specifically Southwest DU). Market research indicated that protein is an important pricing factor for all SWH and DU originating in the Southwestern United States, so this analysis relied on pricing data from U.S. Wheat Associates for SWH and private communication for Southwest DU.

Discussion of Results

The three critical components used to estimate an increase or decrease in the value of stocks for each class were: 1) the weighted mean difference between ANN and PLS results based on the domestic samples from the pilot study (see Table 3). Specifically, the weighted mean difference was rounded to the nearest tenth percent to coincide with common marketing practice (i.e., the market assesses premiums and discounts on a tenth percent protein); Further, the analysis used 2) the magnitude of ending stocks for the 2002/2003 marketing year; and 3) protein premiums and discounts. A change in any one of these components, such as an increase or decrease in stocks or in the protein calibration, would likely result in different valuations of wheat stocks.

Table 3. Summary of Pilot Study Field Results

Class	Samples *(#)*	- - Field Results - - PLS Mean	ANN Mean (% Protein)	Mean Diff.	Std. Dev. of Diff. (% protein)
HRW	72	12.82	12.77	-0.05	0.11
HRS	47	14.75	14.73	-0.02	0.16
HDWH	68	12.64	12.71	+0.07	0.18
SWH	32	10.63	10.56	-0.07	0.15
SRW	42	10.38	10.49	+0.11	0.12
DU	48	13.24	13.51	+0.27	0.15
All Domestic Samples	309	12.58	12.58	0.00	0.16

Hard Red Winter Wheat

Based on data collected from the GIPSA pilot study, the weighted mean difference for ANN compared to PLS was -0.05 percent (i.e., -0.1 percent).

USDA estimated ending HRW stocks at the end of the 2002/2003 marketing year to be 189 million bushels or 5.1 million metric tons, well below the 5-year average of 394.8 million bushels or 10.7 million metric tons.

Ending HRW stocks are anticipated to be well above average in protein content predicated on unusually high protein in last year's crop - - 13.4 percent in 2002 (on a 12 percent moisture basis) versus a 12.1 percent 5-year average. Protein premiums have been impacted by the relative size and protein levels of remaining HRW supplies. The market typically pays a premium for HRW with protein levels above the unspecified or "ordinary" level (i.e., above harvest average). The premium tends to rise steadily, reaching a maximum in the 14 to 15 percent range, beyond which little HRW is commercially traded. May 2003 premiums began at 12.0 percent protein and were running at 7 cents per bushel in the 12.0 to 12.5 percent range; 10 cents a bushel in the 12.6 to 14.0 percent range; and dropped back to zero at higher levels.

Corresponding to the small weighted mean difference, low ending stocks, and similarly low premiums at the end of the marketing year, the difference in the value of HRW stocks using the ANN calibration versus the PLS calibration is -$470,000, or 0.06 percent of the total value of HRW (Table 4).

Table 4. HRW – Calculation of Net Impact of Protein Calibration Change

Protein (percent)	Price including premium or discount /1 ($/bu)	Stocks at 5/31/03 /2 (mil. bu.)	Value with PLS calibration /3 (mil. $)	Stocks at 5/31/03 (0.1% decrease in protein) (mil. bu.)	Value with ANN calibration /3 (mil. $)	Net change (mil. $)
<12.0	$3.78	43.41	164.09	50.31	$190.17	$26.08
12.0	$3.85	6.90	26.56	7.27	$27.99	$1.42
12.1	$3.85	7.27	27.99	7.48	$28.80	$0.81
12.2	$3.85	7.48	28.79	7.58	$29.18	$0.38
12.3	$3.85	7.58	29.18	7.77	$29.91	$0.73
12.4	$3.85	7.77	29.91	8.13	$31.30	$1.39
12.5	$3.85	8.13	31.30	8.06	$31.03	($0.27)
12.6	$3.88	8.06	31.27	7.67	$29.76	($1.51)
12.7	$3.88	7.67	29.76	7.47	$28.98	($0.78)
12.8	$3.88	7.47	28.98	7.12	$27.63	($1.36)
12.9	$3.88	7.12	27.62	6.78	$26.31	($1.32)
13.0	$3.88	6.78	26.30	6.34	$24.60	($1.71)
13.1	$3.88	6.34	24.59	6.05	$23.47	($1.13)
13.2	$3.88	6.05	23.47	5.55	$21.53	($1.94)
13.3	$3.88	5.55	21.53	5.26	$20.41	($1.13)
13.4	$3.88	5.26	20.40	4.80	$18.62	($1.78)
13.5	$3.88	4.80	18.62	4.62	$17.93	($0.70)
13.6	$3.88	4.62	17.92	4.31	$16.72	($1.20)
13.7	$3.88	4.31	16.72	3.76	$14.59	($2.13)
13.8	$3.88	3.76	14.58	3.24	$12.57	($2.02)
13.9	$3.88	3.24	12.57	2.94	$11.41	($1.16)
14.0	$3.88	2.94	11.40	2.53	$9.82	($1.59)
>14.0 and higher	$3.78	16.48	62.29	13.95	$52.73	($9.56)
	TOTAL OF ABOVE		**725.93**		**$725.47**	**($0.47)**

1/ Protein premiums and discounts refer to premiums and discounts reported in the USDA/Farm Service Agency's *Daily Market Rates and Export Grain Values* for the Kansas City HRW market at close of business May 30, 2003.
2/ Ending stock values were from the September 2003, USDA/WADSE report.
3/ Individual values for each protein level may not compute due to rounding.

Hard Red Spring Wheat

Because the overall mean difference between the ANN and PLS calibrations for HRS rounds to 0.0 (from -0.02), the change in value of HRS stocks, based solely on the data and market conditions obtained in preparing this report, is $0.00.

Hard White Wheat

The data collected from the GIPSA pilot study showed that the weighted mean difference for HDWH for ANN compared to PLS was +0.07 percent (i.e., +0.1 percent). However, in the United States, HDWH is grown primarily under contract with premiums based largely on contracted production and, to a lesser extent, on the HDWH planting incentives in the current Farm Bill. Protein content normally does not generate premiums or discounts. Therefore, this analysis anticipates no difference in the value of HDWH stocks.

Soft White Wheat

Based on data from the GIPSA pilot study, the weighted mean difference for SWW for ANN compared to PLS was -0.07 percent (i.e., -0.1 percent).

U.S. Wheat Associates' estimate of ending SWH stocks for the 2002/2003 marketing year was 74 million bushels or 2.0 million metric tons, approximately 10 percent below the 5-year average of 83 million bushels or 2.2 million metric tons.

As with HRW, remaining SWH stocks have higher-than-average protein content - - 10.8 percent in 2002 versus a 5-year average of 10.2 percent. Generally, the market pays a premium for SWH with lower protein levels, in contrast to HRW for which premiums tend to increase with protein levels. Different end uses for SWH, and foreign customers such as Japan and South Korea that prefer lower protein levels, contribute to the this inverse relationship between pricing and protein. According to U.S. Wheat Associates, premiums at the end of the 2002/2003 marketing year were running high at the lower protein levels due to short supplies in these ranges. This shortage is due to last year's dry weather, which resulted in a small crop and unusually high protein levels. At the end of the marketing year, the market was paying premiums up to 44 cents per bushel for SWH with 8.5 percent protein or lower. Premiums for SWH with 8.6 to 9.5 percent protein were running 8 cents per bushel.

A 0.1 percent reduction across the full protein range for SWH would increase the value of ending SWH stocks by $240,000, or about 0.08 percent (Table 5). Higher SWH stock values would primarily benefit the Pacific Northwest (PNW), where the overwhelming majority of SWH is produced, sold, and exported.

Table 5. SWH – Calculation of Net Impact of Protein Calibration Change

Protein (percent)	Price including premium or discount /1 ($/bu)	Stocks at 5/31/03 /2 (mil. Bu.)	Value with PLS calibration /3 (mil. $)	Stocks at 5/31/03 (0.1% decrease in protein) (mil. Bu.)	Value with ANN calibration /3 (mil. $)	Net change (mil. $)
≤ 8.5	4	1.99	7.96	2.40	9.60	1.64
8.6	3.64	0.41	1.49	0.38	1.38	-0.11
8.7	3.64	0.38	1.38	0.47	1.71	0.33
8.8	3.64	0.47	1.71	0.54	1.97	0.25
8.9	3.64	0.54	1.97	0.64	2.33	0.36
9	3.64	0.64	2.33	0.72	2.62	0.29
9.1	3.64	0.72	2.62	0.92	3.35	0.73
9.2	3.64	0.92	3.35	0.93	3.39	0.04
9.3	3.64	0.93	3.39	1.09	3.97	0.58
9.4	3.64	1.09	3.97	1.13	4.11	0.15
9.5	3.64	1.13	4.11	1.14	4.15	0.04
≥ 9.6 and higher	3.56	64.79	230.65	63.65	226.59	-4.06
	TOTAL OF ABOVE		264.93		265.17	0.24

1/ Protein premiums and discounts refer to premiums and discounts obtained through U.S. Wheat Associates' *Price Reports* at close of business May 30, 2003.
2/ Ending stock values were obtained from the September 2003 USDA/WADSE report.
3/ Individual values for each protein level may not compute due to rounding.

Soft Red Winter Wheat

The data collected from the GIPSA pilot study showed that the weighted mean difference for SRW for ANN compared to PLS was +0.11 percent (i.e., +0.1 percent) higher. Since protein content generally does not incur a premium or discount in SRW, this analysis anticipates no impact on the value of stocks.

Durum Wheat

DU represents a unique situation. It is grown in divergent conditions in the primary growing regions, the Northern Plains and the desert Southwest (i.e., California and Arizona), and each region has unique protein levels and values placed on them. DU from the Northern Plains, which accounts for approximately 78 percent of DU production, typically has adequate protein content (minimum 13 percent on 12 percent moisture basis) for meeting semolina requirements. As a result, protein premiums do not usually exist. Rather, premiums are based on falling number, and the percent of hard and vitreous kernels of amber color. In the desert Southwest, which accounts for approximately 22 percent of production, protein content may go below 13 percent. Thus, premiums and discounts are part of the market, with discounts being more common than premiums.

For all DU, the data collected from the GIPSA pilot study showed that the weighted mean difference for ANN compared to PLS was +0.27 percent (i.e., +0.3 percent). The weighted mean differences for ANN versus PLS were +0.25 percent (i.e., +0.3 percent) for Northern Plains DU and +0.37 percent (i.e., +0.4 percent) for Southwest DU. Since DU protein is not a pricing factor in the Northern Plains, this analysis anticipates no difference in the value of Northern Plains DU stocks when comparing the ANN and PLS calibrations. In the desert Southwest, where protein is a pricing factor, the value of desert Southwest DU stocks using the ANN calibration versus the PLS calibration would increase $300,000, only 1.0 percent of the total value of desert Southwest DU (Table 6).

Table 6. Southwest DU – Calculation of Net Impact of Protein Calibration Change

Protein (percent)	Price including premium or discount /1 ($/bu)	Stocks at 5/31/03 /2 (mil. Bu.)	Value with PLS calibration /3 (mil. $)	Stocks at 5/31/03 (0.1% decrease in protein) (mil. Bu.)	Value with ANN calibration /3 (mil. $)	Net change (mil. $)
< 12	$3.93	0.46	$1.81	0.29	$1.14	($0.67)
12.0	$4.68	0.06	$0.28	0.04	$0.19	($0.09)
12.1	$4.68	0.06	$0.28	0.04	$0.19	($0.09)
12.2	$4.68	0.07	$0.33	0.05	$0.23	($0.09)
12.3	$4.68	0.07	$0.33	0.04	$0.19	($0.14)
12.4	$4.83	0.09	$0.43	0.06	$0.29	($0.14)
12.5	$4.83	0.09	$0.43	0.06	$0.29	($0.14)
12.6	$4.98	0.10	$0.50	0.07	$0.35	($0.15)
12.7	$4.98	0.12	$0.60	0.07	$0.35	($0.25)
12.8	$4.98	0.13	$0.65	0.09	$0.45	($0.20)
12.9	$4.98	0.12	$0.60	0.09	$0.45	($0.15)
13.0	$5.13	0.21	$1.08	0.10	$0.51	($0.56)
> 13.0	$5.16	4.58	$23.63	5.16	$26.63	$2.99
	TOTAL OF ABOVE		**$30.94**		**$31.25**	**$0.30**

1/ Protein premiums and discounts refer to premiums and discounts obtained through private communication.
2/ Ending stock values were estimated from figures reported in the September 2003, USDA/WADSE report and the July 2003 USDA/National Agricultural Statistical Services' *Crop Production* report.
3/ Individual values for each protein level may not compute due to rounding.

APPENDIX A

Statistical Analysis of Data

In considering migrating to the ANN approach, GIPSA will consider the accuracy of the method in addition to its economic impact. Accuracy is measured by comparing ANN values to the reference method, the CNA. GIPSA analyzed the data from the study to determine (1) how the ANN calibration performs compared to the CNA and if there were any indicators that the ANN calibration was not robust for a particular class, location and/or protein level; (2) how the ANN performs compared to the current PLS calibration to anticipate caution flags regarding migration to the ANN; and (3) how the PLS performs compared to the CNA.

To determine accuracy, GIPSA used the same domestic data collected from GIPSA's pilot study that were used for the economic analysis. The sampling design of the study called for equal numbers of samples from regions and by protein ranges, allowing collection of more information from areas of lesser production. Consistent with the economic analysis, the data were weighted based on national production to reflect how wheat is really distributed in the country as a whole. This helped identify whether certain classes, protein levels, or regions have problems measuring protein using either PLS or ANN.

GIPSA determined the most meaningful statistics were the mean of differences between each of the calibrations and the CNA. Thus, computing the mean differences and the standard deviation of the mean differences provided information on the robustness of the ANN calibration and the performance of the PLS calibration. GIPSA also used graphical analysis to analyze general trends for the two calibrations.

Figures 1 and 2 are pictorial representations of the raw data. The figures clearly indicate a tighter distribution of points around the regression line for the ANN compared to the PLS; smaller 99 percent confidence limit intervals for the ANN than the PLS; and a smaller bias for the ANN calibration than for the PLS, indicating the ANN calibration is more consistent.

Tables 1 through 3 present the mean differences and the standard deviation of mean differences for both ANN and PLS vs. CNA overall; by class; and class by region by protein content. The statistics are for the field offices' data set only, since impacts to the trade will be generated by machines located in the field. GIPSA has a similar data set for the master machines at TSD. Negative values indicate the PLS or ANN mean was lower than the CNA mean. N is the number of samples in the data set. Mean difference values approaching zero are ideal.

Figure 1. ANN vs. CNA.

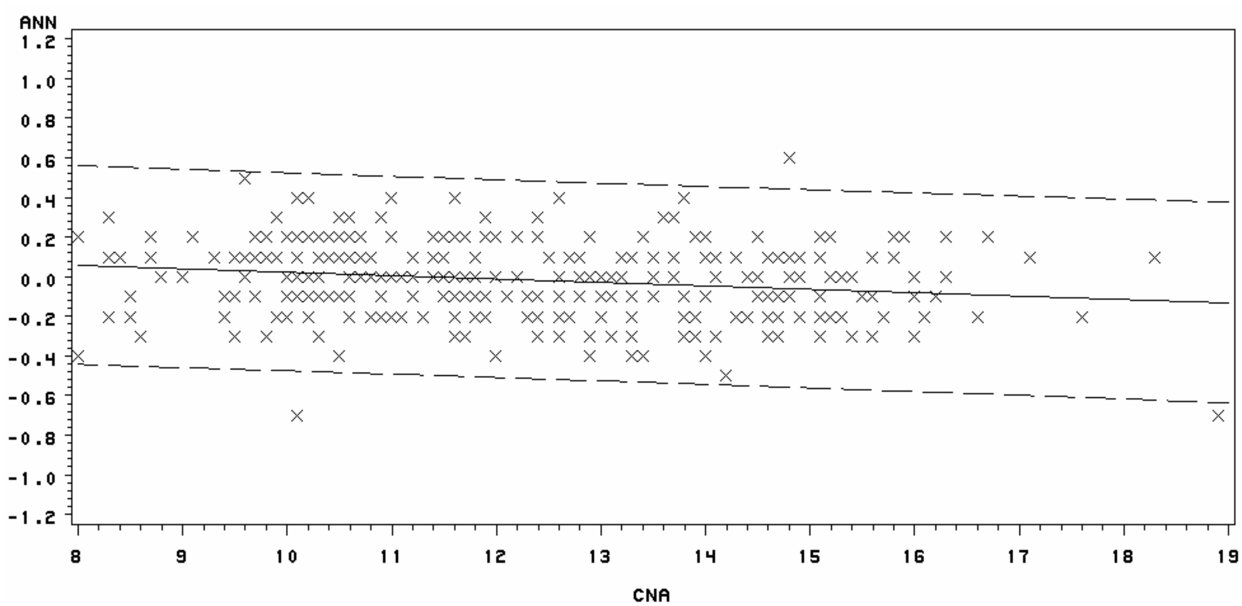
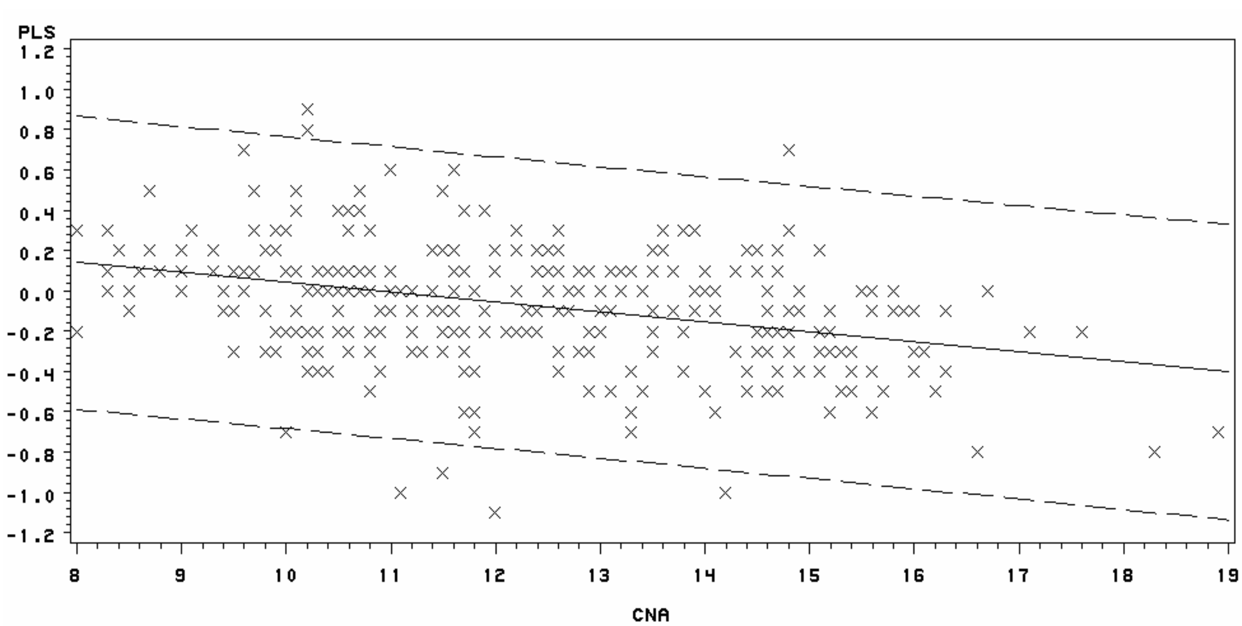


Figure 2. PLS vs. CNA.



The overall effects of the statistical analysis are presented in Table 1. Based on overall mean differences, the ANN predicts protein content with the same accuracy as the PLS. Averaged over all samples in the study, mean differences for ANN and PLS compared to CNA have a magnitude of 0.002 percent (values were -0.001 percent and 0.001 percent respectively). This, in and of itself, indicates there is no identified reason or advantage to migrate from the PLS to the ANN.

Table 1. Overall Effects

CLASS	N=	PLS:CNA MEAN DIFF	ANN:CNA MEAN DIFF	PLS:CNA STD DEV	ANN:CNA STD DEV
ALL	309	0.00	0.00	0.24	0.18

However, the standard deviation of differences (STD DEV of DIFF's) shows that the ANN has a standard deviation about one fourth less than that of the PLS as indicated by the tighter distribution of data points about the regression line for the ANN. Lower standard deviation values mean a smaller possible range of results. For example, with standard deviation of 0.18, and a target of 13.40 percent, there would be an expected range of values from 13.04 percent to 13.76 percent 95 percent of the time. With standard deviation of 0.24, and a target of 13.40 percent, the expected range of values is from 12.92 percent to 13.88 percent, 95 percent of the time. Thus, the probability of providing an incorrect result is greater with larger standard deviation.

Table 2. Wheat Class Effects

CLASS	N=	PLS:CNA MEAN DIFF	ANN:CNA MEAN DIFF	PLS:CNA STD DEV	ANN:CNA STD DEV
DU	48	-0.43	-0.16	0.17	0.17
HDWH	68	-0.14	-0.07	0.19	0.15
HRS	47	-0.01	-0.04	0.22	0.13
HRW	72	+0.12	+0.07	0.19	0.16
SRW	42	-0.08	+0.03	0.17	0.14
SWH	32	-0.06	-0.12	0.24	0.21

Table 2 delineates the data by class of wheat. Except for HRS and SWH, the ANN mean difference is less than for the complementary PLS mean difference. In the cases of HRS and SWH wheat, the PLS mean difference is closer to the CNA, thus ANN could under predict protein content to a slightly greater extent than the PLS. Lower protein content is valued in SWH so likely this would not generate concern, but it might for HRS, for which higher protein content is valued. Fortunately, the HRS under-prediction is insignificant. Also, rounding to one decimal place, which is the case on certificates, may negate this difference.

The PLS mean difference for DU wheat indicates a substantial difference from the reference method. The factors of hard and vitreous kernels of amber color (HVAC) and falling number, not protein, drive DU premiums in the Northern Plains where the bulk of DU is produced. However, premiums for higher protein play a big part in the Southwest DU markets. The ANN offers significant improvement over PLS for predicting protein content of DU wheat. GIPSA is analyzing whether the ANN calibration adequately represents DU and SWH given the ANN:CNA mean difference of -0.16 percent for DU and -0.12 percent for SWH.

Table 2 shows that the ANN has smaller standard deviation than PLS in every wheat class except DU, where it is identical to PLS. The biggest improvement in standard deviation is for HRS. The results indicate that the ANN reduces the likelihood of reporting an incorrect value compared to PLS, for all classes of wheat (except DU where no improvement was seen). Generally speaking, the grain trade wants and expects consistent results and the ANN improves consistency.

Table 3 further refines the statistical analysis by class by region by protein level. In this table, the mean CNA protein value is shown, allowing us to see how the ANN compares to PLS in certain protein ranges (low vs. medium vs. high). The effect of weighting the data by production manifests itself in this table. (See footnote at Table 3.)

Looking at mean DIFFs for DU wheat, PLS underestimates the protein content at every location and protein range relative to the reference. The PLS performance is particularly poor for California DU. It appears that the PLS has a location problem which the ANN clears up. Northern Plains DU is underestimated by the PLS compared to the ANN- but not as dramatically. Nothing in the standard deviation analysis for DU is remarkable. ANN values are generally lower than PLS, but not significantly.

For HDWH, the Northwest midrange has the highest production weighting. ANN predicts protein content closer to the reference for that group of samples as well as the Kansas midrange, but the PLS is very slightly closer to the CNA for the California HDWH midrange samples. Analysis of standard deviation of differences indicates that ANN has generally lower values and in the cases where ANN is higher, the difference in not significant.

The astute reader will note that in the case of HRS, as presented in Table 2, the ANN has a larger mean DIFF than PLS. However nothing in the HRS entries at Table 3 suggests this should be the case. The largest negative mean DIFF values are associated with PLS. The second entry under North Central HRS (medium protein range) has the heaviest component weighting and shows that the ANN is closer to the CNA value than the PLS, while being only slightly negative (and rounding to zero). Combined with the low protein North Central HRS fraction (entry one) there is enough weight to make the HRS class ANN value (Table 2) more negative than the corresponding PLS value. However,

Table 3. Wheat Class by Location and by Protein Range Effects

CLASS	LOCATION	N	PRO% CNA	PLS:CNA MEAN DIFF	ANN:CNA MEAN DIFF	PLS:CNA STD DEV	ANN:CNA STD DEV
DU	NORTH	8	11.45	-0.23	0.06	0.21	0.14
DU*	NORTH	8	13.77	-0.44	-0.19	0.15	0.16
DU	NORTH	8	15.59	-0.40	-0.21	0.14	0.13
DU	CALIFORNIA	8	11.17	-0.74	-0.06	0.22	0.22
DU	CALIFORNIA	8	13.85	-0.50	-0.17	0.19	0.18
DU	CALIFORNIA	8	15.52	-0.38	-0.02	0.20	0.18
HDWH	NORTHWEST	8	10.13	-0.11	-0.11	0.19	0.10
HDWH*	NORTHWEST	8	12.19	-0.18	-0.10	0.09	0.10
HDWH	NORTHWEST	8	14.47	0.04	0.13	0.30	0.24
HDWH	KANSAS	4	10.33	0.02	-0.01	0.04	0.03
HDWH	KANSAS	8	12.69	-0.06	-0.15	0.13	0.15
HDWH	KANSAS	8	15.21	-0.27	-0.11	0.22	0.20
HDWH	CALIFORNIA	9	9.75	0.12	0.08	0.24	0.10
HDWH	CALIFORNIA	7	11.56	0.03	0.05	0.13	0.11
HDWH	CALIFORNIA	8	14.74	-0.12	0.00	0.19	0.18
HRS	NORTH CENTRAL	7	12.41	0.10	-0.06	0.22	0.15
HRS*	NORTH CENTRAL	8	14.48	0.11	0.00	0.11	0.08
HRS	NORTH CENTRAL	8	15.91	-0.04	0.00	0.08	0.14
HRS	WEST	8	12.25	-0.13	-0.08	0.13	0.13
HRS	WEST	7	14.21	-0.25	-0.14	0.27	0.16
HRS	WEST	9	16.50	-0.39	-0.17	0.26	0.25
HRW	WEST CENTRAL	10	10.62	0.20	0.14	0.21	0.16
HRW*	WEST CENTRAL	6	12.32	0.18	0.05	0.20	0.19
HRW	WEST CENTRAL	8	13.58	0.05	0.07	0.18	0.16
HRW	NORTH	8	10.07	0.10	0.12	0.24	0.13
HRW	NORTH	8	12.17	0.10	0.09	0.15	0.19
HRW	NORTH	8	14.01	0.03	0.11	0.15	0.12
HRW	CALIFORNIA	8	10.19	0.56	0.24	0.19	0.20
HRW	CALIFORNIA	8	12.01	0.31	0.17	0.18	0.14
HRW	CALIFORNIA	8	13.81	0.01	0.01	0.16	0.20
SRW	MIDWEST	9	9.63	0.05	0.05	0.15	0.16
SRW*	MIDWEST	5	10.55	0.01	0.05	0.07	0.08
SRW	MIDWEST	5	11.81	-0.18	0.06	0.06	0.15
SRW	SOUTH	2	10.00	-0.21	-0.06	0.06	0.10
SRW	SOUTH	12	10.52	-0.23	-0.02	0.17	0.18
SRW	SOUTH	3	11.30	-0.21	-0.05	0.08	0.06
SRW	EAST	3	9.62	0.27	0.16	0.06	0.08
SRW	EAST	3	10.52	-0.09	0.05	0.12	0.10
SWH	WEST	8	8.32	0.09	-0.07	0.18	0.25
SWH*	WEST	9	10.11	-0.02	-0.09	0.19	0.20
SWH	WEST	7	12.68	-0.20	-0.22	0.35	0.24
SWH	EAST	2	8.85	0.11	0.05	0.06	0.07
SWH	EAST	6	9.35	0.02	-0.06	0.13	0.11

* Denotes fraction weighted most heavily within the class.

the ANN actually out performs the PLS in the fraction where the bulk of the samples are resident. Thus with the bulk of HRS samples in the North Central group, ANN performs better than PLS, and it appears that the PLS has a location problem which becomes less problematic with the ANN.

HRW mean DIFF data show that for West Central, where the bulk of production weighting is distributed, the ANN is closer to the reference method. Standard deviation analysis shows smaller values for the ANN, thus an improvement over PLS. California appears problematic for the PLS but the ANN improves this relative to the CNA. It appears that the PLS has a location problem for California HRW. Nevertheless, the ANN will potentially lower the protein result slightly for California HRW, primarily in the low protein range and very slightly in the medium protein range (but not in the high protein range). It is noted however, that California HRW production comprises just 1.5% of U.S. HRW production (for 2003) and the low protein component would be a small fraction of that. Thus the impact of lowering the protein content of the low protein fraction of California HRW should not be dramatic.

Midwest SRW midrange protein has the bulk of production weighting and mean DIFF values are slightly higher for the ANN compared to the PLS. Generally, Midwest SRW ANN values are closer to CNA values than the PLS. Standard deviation values are slightly higher for Midwest SRW at all 3 protein ranges, but not significantly. Other SRW data is generally not remarkable.

West SWH midrange protein has the bulk of production weighting and the mean DIFF values are more negative for ANN than PLS at all protein levels, suggesting that ANN would predict a lower value than PLS-not problematic in SWH. Standard deviation of difference values are slightly higher for ANN at the low and medium protein levels but probably not significantly.